Geoacoustic Database Development for the ESME Initiative

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LONG-TERM GOALS

Our long-term objective is to establish a database of sediment and bottom properties including sediment compressional wave speed, shear wave speed, attenuation and density. Using this we propose to provide the best sediment model for any region with estimates of model uncertainty. These data would be appropriate for incorporation in state-of-the-art propagation models for acoustic effects prediction on the marine environment.

OBJECTIVES

1. Develop a surficial sediment model for the world's oceans based on optimal estimation techniques, geological models and data.
2. Integrate the sediment model into the ESME module.
3. Provide estimates for model uncertainty.
4. Apply this model in selected regions to test its accuracy and effectiveness.

APPROACH

As a first step we collect all the available sediment property data at the region of interest. This includes all the geoacoustic (compressional wave speed, shear wave speed, attenuation etc.) and geotechnical properties (bulk density, permeability, porosity etc.). In addition other useful sources of information like sediment thickness maps, geophysical survey records etc. are also used. The geotechnical properties can be used to derive geoacoustic properties using a suitable model. These data can be obtained from literature or from available sediment property databases. All this data is then used to efficiently estimate the sediment properties at any location within the region of interest.

WORK COMPLETED

Sediment models suitable for the Southern California Bight (SOCAL) region and the Middle Atlantic Bight region were developed and integrated into the ESME module as part of the two test cases. The third test case was at the VAST site. A program was written to generate sediment parameters for the VAST test region. The location lies between latitudes 33 N and 40 N and 71 W and 77 W. The program is written in such a way that given the location and the frequency of interest, the sediment properties are estimated using all the available data.
In addition, an EOF based representation was developed for the East China Sea region. Data for this came from the ASIAEX experiment sponsored by ONR. Sediment properties were interpolated using

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14. ABSTRACT
Our long-term objective is to establish a database of sediment and bottom properties including sediment compressional wave speed, shear wave speed, attenuation and density. Using this we propose to provide the best sediment model for any region with estimates of model uncertainty. These data would be appropriate for incorporation in state-of-the-art propagation models for acoustic effects prediction on the marine environment.

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this approach and compared with results from long range sediment tomography. The results are described in detail in the following sections.

RESULTS

A. Sediment models for ESME test region (VAST)

Sediment models suitable for the Southern California Bight (SOCAL) region and the Middle Atlantic Bight region were developed and integrated into the ESME module as part of the two test cases. The third test case was at the VAST site. A program was written to generate sediment parameters for the VAST test region. The location lies between latitudes 33 N and 40 N and 71 W and 77 W. The program is written in such a way that given the location and the frequency of interest, the sediment properties are estimated using all the available data.

The bottom properties are specified for a simple two layer model. Some of the properties (compressional and shear speeds in the basement) are assumed constant throughout the area. The sediment information available include core data, sediment maps, sediment type information etc. For this location we were able to find some historical data which are listed below.

1. Core data:
   Atlantic Margin Coring Sites 6006 to 6012 and 6020 to 6021[1,2]. The sediment type information, sediment properties, layer thickness etc. were obtained from these.
   Deep Sea Drilling sites, 902 to 906.
2. Sediment type information: from USGS Open File Report[3].
3. Sediment sound velocity functions for North Atlantic (Houtz)[4]
4. Thickness of surficial sand sheet (Knebel and Spiker)[5]
5. Sediment and geoacoustic models:
   Hamilton model[6]: Used for predicting the compressional and shear wave speeds as well as attenuation as function of frequency for different sediment types.
   Bowles[7]: Used for predicting attenuation as a function of frequency and shear speeds for known sediment types .
   Biot- Stoll model[8] to compute the compressional and shear wave speeds from sediment paramaters.
6. Sediment layer thickness maps: Used for predicting the sediment thickness.

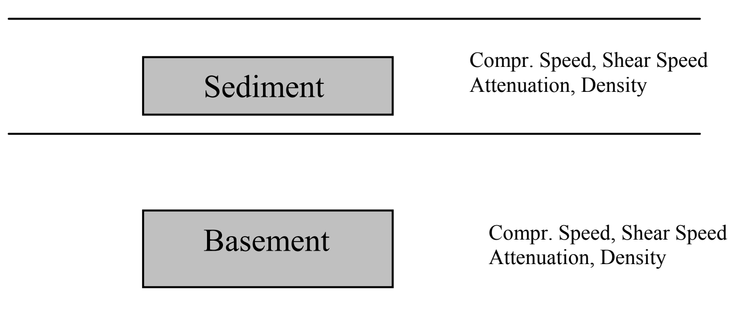

Figure 1. Two layer model to represent the sediment properties used in this study.

The program uses these data to arrive at the sediment parameters at a given location. The sediment compressional speed is estimated using the core data, sediment type information and the Hamilton's

values for these sediment types. Sediment thickness is estimated based on the core data and sediment thickness map. Shear speed, and Compressional and shear attenuation are determined mainly using the sediment type information and predictions by Hamilton and Stoll. The bottom properties are specified for a simple two layer model. Some of the properties (compressional and shear speeds in the basement) are assumed constant throughout the area. The output parameters are written in a text file.

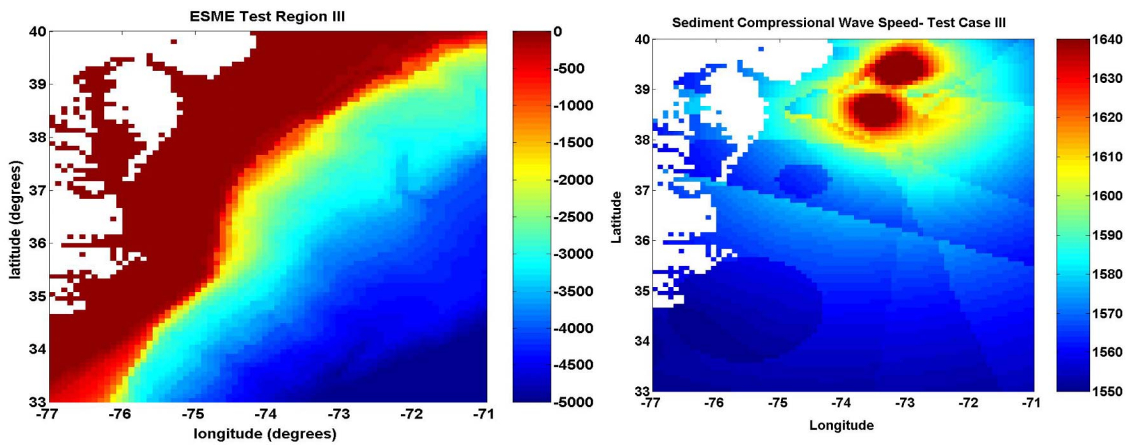

Figure 2. Left panel shows the location of the ESME test case and the bathymetry. Right panel shows the sediment sound speed obtained using the sediment model developed.

B. Empirical Orthogonal Function (EOF) based representation of sediment properties.

EOFs have been used to represent variations in ocean sound speeds for a long time. They have also been used to represent variations in sediment properties recently[9]. EOFs provide an efficient means of representing measurements as a set of components or modes that are uncorrelated. Observations of any field can be expressed as a sum of the mean and a perturbation. These field perturbations can then be expressed as a sum over the EOF basis vectors incorporating sufficient number of modes to capture most of the variations. The procedure for implementing this in the context of sediment modeling is described in detail by Jay et al.[9] We have tried to use this approach to East China Sea location which was the site for the ASIAEX experiment sponsored by ONR. As part of the experiment various geoacoustic measurements were taken which included gravity and piston cores, water gun and chirp surveys.

Figure 3 shows the result of the EOF based interpolation and its comparison with sediment tomography inversions. The core profiles from locations indicated in the left panel of the figure are used to obtain the EOFs. The sediment speeds at three locations along a source- receiver path is then estimated using the EOFs using the approach given in Jay et al[9]. The right panel shows the comparison of these interpolated profiles with the tomography inversions. The tomography inversions produce a mean profile calculated from the Genetic Algorithm solutions and also a profile from the hybrid approach. Potty et.al[10]. have discussed this inversion scheme in detail.

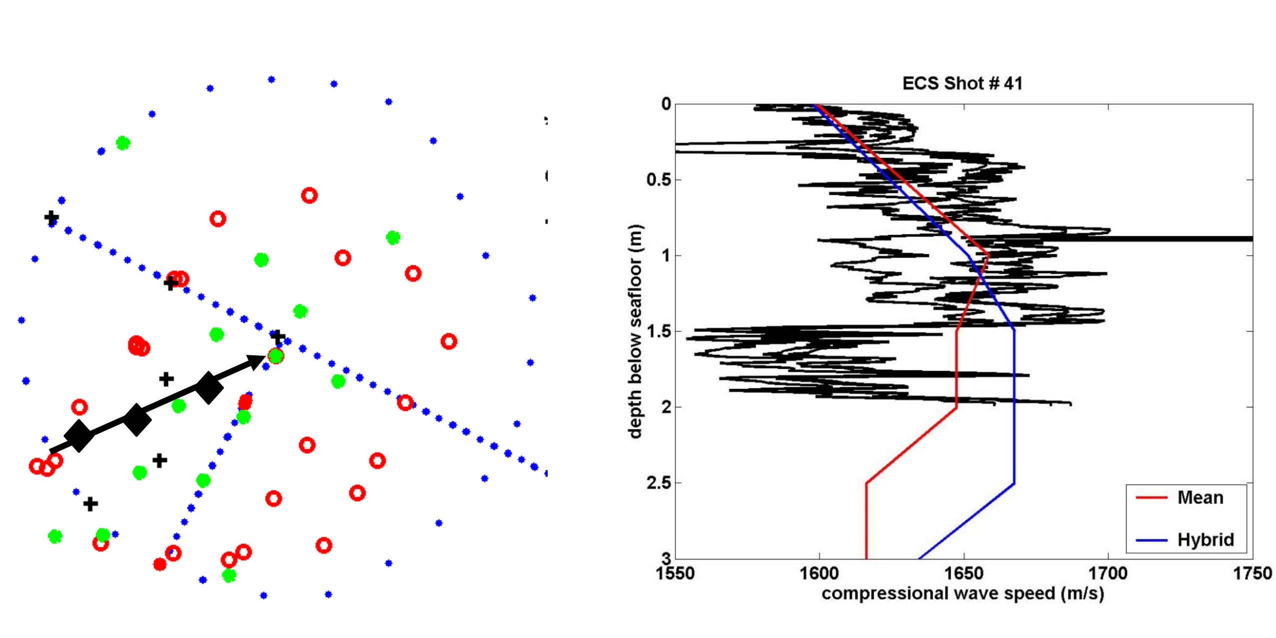

Figure 3. Left panels shows the distribution of the cores in the experimental area. The radius of the circle is approximately 30 km. The blue asterisks are explosive charges used for sediment tomography. The EOF based approach is used to interpolate the sediment sound speed at three locations (black diamonds) along the propagation path from one of the explosive charge to the receiver which was at the center of the circle. Right panel shows the interpolated sediment speed data compared with tomography inversions

C. Future work planned

Our future goals include the following:

1. Use the EOF based representations to efficiently incorporate geophysical data into the sediment model
2. Provide some measure of uncertainty to the estimates.

IMPACT/APPLICATIONS

Our effort is intended to provide the best possible estimates of sediment data needed for the propagation modeling component of the ESME initiative. This will enable the propagation modelers to use 'best guesses' when direct estimates of the sediment data is not readily available.

TRANSITIONS

We expect that this sediment model, when complete, will be useful to the acoustic community as a whole as an important database of sediment property information.

RELATED PROJECTS

We have used data from the ASIAEX experiment sponsored by ONR to test the EOF based representations for sediment properties. These representations will eventually be useful for geoacoustic modeling of sediments.

REFERENCES

1. Hathaway J. C et al., “U.S. Geological Survey Core Drilling on the Atlantic Shelf,” Science, 206(2), (1979).

2. Richards. A. F, “Atlantic Margin Coring Project 1976- Preliminary report on shipboard and laboratory geotechnical data,” US. Geol. Surv. Open File Report 78-123, (1977).

3. USGS Open File Report, OFR-00-356; http://pubs.usgs.gov/of/of00-356/

4. Houtz. R. E, “Comparison of sediment sound velocity functions from conjugate margins,” Geo. Soc. Am. Bull., 92(1), (1981).

5. Knebel. H. J, and Spiker. E., “Thickness and age of surficial sand sheet Baltimore Canyon area,” Am. Aasoc. Petr. Geo. Buul., 61, (1977).

6. Hamilton E. L, “Geoacoustic modeling of the sea floor, “J. Acoust. Soc. Am. 68(5), (1980).

7. Bowles F. A, “Observation on attenuation and shear-wave velocity in fine grained marine sediments,” J. Acoust. Soc. Am. 101 (6), (1997)

8. Badiey M, Cheng A, and Mu. Y, “From geology to geoacoustics- Evaluation of Biot- Stoll sound speed and attenuation for shallow water acoustics,” J. Acoust. Soc. Am., 95, (1994).

9. Jaye M, Badiey M, and Siegmann W. L, “Geoacoustic profile estimation using Empirical Orthogonal Functions for propagation applications,” IEEE J. Oceanic Eng., 28(2), (2003)

10. Gopu Potty**,** James Miller, James Lynch and Kevin Smith, "Tomographic Inversion for sediment parameters in shallow water," J. Acoust. Soc. Am. 108(3), Pt.1, 973-986, (2000).

PUBLICATIONS

1. G. R. Potty, J. H. Miller and J. F. Lynch, “Inversion of sediment geoacoustic properties at the New England Bight,” J. Acoust. Soc. Am. (accepted).

2. G. R. Potty and J. H. Miller, “Tomographic mapping of sediments in shallow water,” IEEE. J. Oceanic Eng., 28(2), 2003.

3. Gopu Potty**,** James Miller, Peter Dahl and Colin Lazauski, “Geoacoustic inversion results from the ASIAEX East China Sea Experiment,” IEEE J. Oceanic. Eng. (submitted)

4. Colin Lazauski, James Miller and Gopu Potty, “The use of Airy phase measurements for geoacoustic inversion; ASIAEX East China Sea Experiment,” IEEE J. Oceanic. Eng. (submitted).

5. Kunde Yang, Yuanliang Ma, Chao Sun, James Miller and Gopu Potty, “Multi-step matched field inversion for broad band data from ASIAEX 2001,” IEEE J. Oceanic. Eng. (submitted)

6. James Miller, Louis Bartek, Gopu Potty, Dajun Tang, Jung Na and Yiguan Qi, "Sediments in the East China Sea," IEEE J. Oceanic. Eng. (submitted).

PRESENTATIONS/ CONFERENCE PROCEEDINGS

1. James Miller and Gopu Potty, "The influence of bottom properties on the acoustic environment in shallow water," Environmental Consequences of Underwater Sound (ECOUS) conference, San Antonio, Texas, p75, 2003.

2. Gopu R. Potty, James H. Miller, Colin J. Lazauski and Chuen-Song Chen, "Optimal search strategies for nonlinear, multi-parameter geoacoustic inverse problems," J. Acoust. Soc. Am. 113(4), p2190, 2003.

3. Gopu R. Potty, James H. Miller, Colin J. Lazauski, James F. Lynch and Arthur Newhall, " Inversion of geoacoustic parameters in the South China Sea," J. Acoust. Soc. Am. 112(5), p2310, 2002.

4. Chuen-Song Chen, James H. Miller, Faye Boudreaux-Bartels, Gopu R. Potty, and Colin J. Lazauski, "Application of matching pursuit algorithm for dispersive acoustic signals," J. Acoust. Soc. Am. 112(5), p2421, 2002.

5. Colin J. Lazauski, James H. Miller, Gopu R. Potty, Chuen-Song Chen and Peter Dahl, " Sediment tomography in the East China Sea: Compressional wave speed and attenuation inversions from Airy phase dispersion measurements and time series correlation," J. Acoust. Soc. Am. 112(5), p2309, 2002.

6. P. G. Cable, R. Gibson, Y. Dorfman, D. P. Knobles, T. W. Yudichak, R. Zhang, Z. Peng, F. Li, Z. Li, P. H. Dahl, J. H. Miller and Gopu R. Potty," A comparison of East China Sea low frequency bottom scattering strength determinations," J. Acoust. Soc. Am. 112(5), p2362, 2002.

7. D. P. Knobles, T. W. Yudichak, Peter Cable, Y. Dorfman, Peter Dahl, J. H. Miller, Gopu R. Potty, Renhe Zhang, Z. Peng, F. Li and Z. Li, "Analysis of time series data in the East China Sea generated from explosive sources," J. Acoust. Soc. Am. 112(5), p2361, 2002.

8. Y. Dorfman, P.G. Cable, D. P. Knobles, T. W. Yudichak, R. Zhang, Z. Peng, F. Li, Z. Li, James H. Miller and Gopu R. Potty, "Separation of scattering mechanisms for the Asian Sea International Acoustics Experiment East China Sea reverberation measurements," J. Acoust. Soc. Am. 112(5), p2254, 2002.

9. T. W. Yudichak, D. P. Knobles, P. Cable, Y. Dorfman, R. Zhang, Z. Peng, F. Li, Z. Li, Peter Dahl, James H. Miller and Gopu R. Potty, "Modeling of reverberation in the East China Sea," J. Acoust. Soc. Am. 112(5), p2254, 2002.

10. Gopu R. Potty, , James Miller, "Broadband Non-linear Inversions in Shallow Water for Geoacoustic Parameters," ICONS 2002- International Conference on Sonar – Sensors and Systems, Kochi, India (2002).

11. J. H. Miller, L. R. Bartek, Gopu R. Potty, P. H. Dahl, C. J. Lazauski, C-S. Chen, and K. Westhoff, "Geoacoustic measurements in the East China Sea," Proceedings, The Asian Seas International Acoustics Experiment (ASIAEX) International Symposium, Chengdu, China, October 14-18, 2002, Technical Report, APL-UW TR 0201, December 2002, p17.